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Implementing Blended Learning within the TPMK Framework to Enhance Mathematics Teachers' Competence

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Abstract: The post Covid-19 pandemic opens opportunities for teachers to conduct innovative studis in the context of mathematics education. The blended learning model has become the primary choice implemented by teachers during mathematics learning activities in schools. However, discourse related to this matter is still limited. This research investigates the impact of implementing the blended learning model on the Technological Pedagogical and Mathematics Knowledge (TPMK) of mathematics teachers in Madrasah Aliyah (MA) in Indonesia. post-Covid-19 pandemic. The research focuses on aspects of blended learning implementation, the level of TPMK of teachers, and the extent of its impact on the professional development of mathematics teachers. The research method used is correlational design, with data collection conducted through questionnaires given to MA teachers. The results show that implementing blended learning has a significant positive impact on improving the TPMK of mathematics teachers. Research recommendations include expanding training programs for teachers in technology integration, improving digital infrastructure in madrasas, providing incentives for learning innovations, and enhancing cooperation among madrasas. The implications of this research are crucial in providing significant contributions to the development of mathematics education in the madrasah environment. This research can be a foundation for developing more effective educational strategies and policies, particularly in facing and adapting to post-pandemic learning changes.

Keywords: *Blended Learning, Competence, Mathematics teachers, TPMK.*

1. Introduction

The competence of teachers in Indonesia is still relatively low. Data shows that 60% of teachers in Jakarta do not plan their lessons well [1]. There is a tendency for teachers to prioritize the material they teach rather than presenting lesson material that considers learning objectives. Another fact reveals that most teachers teach with a monotonous, unappealing instructional model, and very few mathematics teachers try to lead in innovative and creative ways [2]. The domino effect of low teacher competence impacts the low quality of education in Indonesia, as evidenced by Indonesia's low rankings, especially in mathematics. Similarly, the Trends in International Mathematics and Science Study (TIMSS) results in 2020 placed Indonesia 36th out of 49 countries worldwide. Referring to these problem data, during the COVID-19 academic period, mathematics teaching in schools was implemented using two instructional models. Some schools implemented face-to-face learning models (In-Person), while others implemented a blended learning approach. The implementation of the blended learning model can have an impact on improving the competence of madrasa teachers, particularly in technological pedagogical mathematics knowledge (TPMK).

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So far, researchers have extensively conducted studies on applying the Blended Learning model. For instance, Borba et al. implemented a combination of Blended Learning, e-learning, and mobile learning in school mathematics learning activities[3]. Murtikusuma et al. focused more on applying Blended Learning with the assistance of Google Classroom [4]. Meanwhile, the study by Helsa & Kenedi utilized the educational social media platform Edmudo to implement the blended learning model [5]. Based on these three studies, implementing the blended learning model can positively improve the quality of mathematics learning [6]. Implementing the Blended Learning model can also enhance students' mathematical understanding [7], [8]. Meanwhile, the study by Sukma & Priatna states that implementing the Blended Learning model can enhance students' critical thinking skills [9]. The Blended Learning model can also contribute to students' psychological well-being by increasing their motivation to learn mathematics. Based on the existing research findings, very few studies focus on the impact of applying the Blended Learning model on teachers. Research studies have overlooked the competence of teachers required to implement the Blended Learning model. Therefore, this study investigates the relationship between applying the Blended Learning model and TPMK among madrasa teachers.

Based on existing research, this study aims to address the shortcomings of previous research by focusing more on analyzing the TPMK (Technological Pedagogical and Mathematics Knowledge) of madrasa teachers through implementing the blended learning model post-Covid-19 pandemic. In line with this, the research aims to examine three specific aspects. First, to explain the implementation of the blended learning model among madrasa teachers post-Covid-19 pandemic. Second, this study also aims to describe the overview of TPMK of madrasa teachers, which is crucial for their competence in teaching implementation. Third, the research also investigates the impact of implementing the blended learning model on the TPMK of madrasa teachers.

The argumentation built in this research suggests that implementing the blended learning model impacts madrasa teachers' Technological Pedagogical and Mathematics Knowledge (TPMK). The importance of this research lies in its contribution to improving teaching quality by integrating online and face-to-face learning, enriching student learning experiences, addressing challenges in mathematics education, and enhancing the competence of madrasa teachers. Through implementing blended learning in mathematics learning activities, teachers can effectively utilize technology, present engaging lesson materials, provide real-time feedback, and enhance teaching skills. Overall, research on applying blended learning to TPMK teachers improves the quality of education and teacher competence.

2. Literature Review

2.1. Blended Learning

The study on the implementation of blended learning has been extensively conducted. Blended learning is defined as an innovative approach in education that combines face-to-face instruction with online learning [10]. This combination offers a more flexible and personalized learning experience, as students can access learning materials and participate in discussions online while still benefiting from direct interaction with teachers and peers in the classroom. Additionally, blended learning has been shown to enhance student engagement and motivation by offering various learning modalities and opportunities for active participation. The integration of multimedia and interactive online tools in the teaching and learning process also facilitates more efficient and effective use of resources [11]. Overall, blended learning offers numerous advantages, including flexibility, personalization, student engagement, and resource utilization [12]. This approach transforms traditional teaching and learning by combining face-to-face instruction with online components [13], creating a more dynamic and interactive learning experience. Blended learning also encourages independent learning and autonomy by providing students with the ability to access learning materials as needed.

Moreover, blended learning enables differentiated instruction as teachers can tailor online activities and resources to meet the needs and interests of students. As a transformative educational model, blended learning combines the benefits of face-to-face teaching with online learning [14], enhancing

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flexibility for both students and teachers while promoting the development of essential 21st-century skills such as digital literacy and self-directed learning. Nevertheless, the connection between blended learning and the improvement of mathematics teachers' TPMK remains limited in research discourse, making it relevant to explore further in this study.

2.2. Technological Pedagogical Mathematics Knowledge (TPMK)

The study of TPMK, which seeks to integrate pedagogical technology into mathematics education, has gained attention and recognition in recent years. Researchers acknowledge the benefits of using technology in mathematics education as it supports teaching and learning by providing tools and resources that enhance students' understanding and engagement. The integration of technology in mathematics education allows students to develop essential skills such as problem-solving, decision-making, and reflective reasoning [15]. Moreover, it fosters creative thinking skills and encourages mathematical reasoning and thinking [16]. The use of digital technology in mathematics education has also been proven to improve early mathematics abilities [17]. Teachers are expected to teach mathematical content and processes that enhance students' mathematical competence, and educational technology plays a crucial role in supporting mathematics teaching and learning [18]. The integration of technology into mathematics education has numerous benefits that help students investigate and compare various mathematical ideas and provide alternative ways of learning. One specific technology widely used in mathematics education is GeoGebra [15], a dynamic geometry software that allows students to explore and manipulate mathematical concepts.

The prospective mathematics teachers must possess TPMK competence in the 21st-century learning era, where technology-based mathematics learning is applied [19]. In contrast, the support of teacher competence (TPMK) for the implementation of inquiry-based learning with authentic problems [20]. These studies indicate that TPMK contributes to improving the quality of mathematics education in schools. In line with this, the development of teachers' TPMK can contribute to enhancing students' capacity for critical thinking and mathematical communication [21]. The evolution of TPMK research began with studies on Technological Pedagogical Content Knowledge (TPCK). There is a substantial amount of discourse related to TPCK studies, including Koh, Chai, & Lim's study on professional development for TPACK-21CL: Effects on teachers' ICT integration and student learning outcomes [20], He et al.'s study on the structure of TPCK among middle school mathematics teachers in China [22], and Huang's theoretical analysis of the TPACK knowledge structure of mathematics teachers based on the T-TPACK model [23], among many others. These studies have led to the development of the TPMK concept, which is a specification of mathematical technology competence. However, what distinguishes this study is its focus on the implementation of the blended learning model and its implications for mathematics teachers' TPMK. Based on these studies, relevant research can be conducted. These studies have not provided a comprehensive discussion on improving teachers' TPMK competence during the COVID-19 pandemic. Furthermore, these studies have not comprehensively examined the implementation of blended learning, which is a mixed model of offline and online learning.

2.3. Mathematics Teacher Competencies

In addressing the challenges of education in the digital era, Indonesia must prepare a skilled workforce to become a leading nation in the education sector. one of the key steps to achieving this is through the development of teacher competencies, enabling teachers to educate a generation capable of adapting to the advancements of digitalization [24]. The role of teachers has undergone a transformation; they are no longer merely conveyors of information but must also take a more active role in utilizing technology. Teachers need to evolve their roles to remain relevant, as failing to do so could result in their roles being diminished over time. Teacher competence encompasses the knowledge, skills, and behaviors that teachers must possess, master, and effectively implement. This competence is crucial in the context of teaching mathematics [25]. Additionally, the Indonesian Government Regulation No. 19 of 2005 concerning the National Education Standards Agency (BSNP) emphasizes

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that educators or teachers at the primary, secondary, and early childhood education levels must have the competence to act as learning agents. This highlights the expectation that teachers play a central role in transferring knowledge to students. Terminologically, competence is a combination of observable and measurable knowledge and abilities of mathematics teachers [26]. Further define competence as the observable and measurable behavior of mathematics teachers [27]. Thus, mathematics teacher competence is a set of mathematical knowledge, skills, and behaviors that teachers must possess, internalize, master, and demonstrate in performing their professional duties, namely teaching mathematics.

This competence includes pedagogical, personal, social, and professional competencies [28]. These four competencies are holistic, meaning that teachers should not only possess one or more of these skills but must be able to integrate all four aspects. Teachers with pedagogical competence can create quality learning experiences, understand students' needs, and use effective teaching methods. Personal competence, on the other hand, helps build positive relationships between teachers and students, creating a classroom atmosphere that supports students' social and emotional development. Furthermore, social competence enables teachers to interact more effectively with students, enhancing student engagement and motivating them to learn. Meanwhile, professional competence ensures that teachers have a strong understanding of the subject matter, adhere to ethical standards, and continuously develop themselves through training. In the rapidly changing 21st century, competent teachers help prepare students for the future by developing 21st-century skills such as critical thinking, creativity, digital literacy, and adaptability. In addition to providing individual benefits, competent teachers also contribute to the overall improvement of education quality, creating a generation ready to face future challenges.

3. Methods

3.1. Research Design

This research employs a quantitative approach with a Correlational Research design [29]. The aim of the correlational research design in investigating the impact of implementing the blended learning model post-COVID-19 pandemic on the Technological Pedagogical and Mathematics Knowledge (TPMK) of mathematics teachers in Madrasah Aliyah (MA) in Indonesia involves several key aspects. Firstly, this study aims to evaluate the relationship between implementing the blended learning model and improving TPMK among MA teachers. By collecting data on the extent to which mathematics teachers implement the blended learning model and the importance of the impact on TPMK post-implementation of this teaching model, researchers can also determine the results of positive correlation analysis between the two variables. These findings can better explain how implementing the blended learning model influences teachers' technological, pedagogical, and mathematical knowledge. Secondly, this research also seeks to analyze how implementing blended learning impacts the TPMK of madrasa teachers. Additionally, the study offers additional information regarding aspects such as teacher training in using technology, the availability of technological resources in schools, or administrative support for implementing the blended learning model in mathematics education at Madrasah Aliyah.

3.2. Research Procedure

The researchers conducted the study at Madrasah Aliyah (MA) in Cirebon Regency, Indonesia. There are 66 State Madrasah Aliyah (MAN) and Madrasah Aliyah Swasta (MAS) schools in Cirebon-Indonesia. (https://data.sekolah-kita.net). However, the targeted research site specifically focused on State Madrasah Aliyah (MAN) implementing the blended learning model in mathematics learning activities. The target subjects of this research involved mathematics teachers at Madrasah Aliyah (MA) in Cirebon Regency who were engaged in mathematics teaching using the blended learning model. Mathematics teachers at the MA level were the main subjects to explore changes in TPMK. At the same time, students were the subjects to identify responses to implementing the blended learning model. Subject determination for the research used a purposive sampling technique [30]. The selection criteria

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were limited to mathematics teachers at MA who implemented the blended learning model in mathematics teaching at school. In this technique, researchers intentionally selected respondents or sample units based on specific characteristics desired to meet the research objectives. The method used in the Purposive Sampling Technique is Criterion Sampling [31]. In this research, the researcher established specific criteria for selecting mathematics teachers at MA, who became the research subjects, totaling 32 individuals. These criteria may involve the level of experience in teaching mathematics, the level of understanding of technology, or the level of participation in blended learning training post-pandemic. MA teachers who have implemented the blended learning model since the beginning of the pandemic, or who have participated in specific training related to the use of technology in mathematics teaching, were chosen.

This research analyzes the Technological Pedagogical Mathematics Knowledge (TPMK) of mathematics teachers in Madrasah Aliyah (MA). Additionally, it involves studying the impact of implementing the blended learning model. Therefore, the research object centered on teachers allows for more focused research and contributes to understanding the transformation of mathematics education in the post-pandemic era.

3.3. Data Collection Technique

The research instruments used in this study comprise three main types: a questionnaire on the implementation response of the blended learning model, a TPMK questionnaire, and a questionnaire on the implementation of the Blended Learning Model consisting of 20 items using a Likert scale constructed to measure the implementation of the blended learning model in teaching practices. The construction of indicators in this questionnaire involves identifying dimensions or critical concepts relevant to implementing blended learning in mathematics education. The development of the instrument refers to studies consisting of dimensions of usage, content types, educational involvement, digital resources, and collaboration [3], [6], [32].

The TPMK questionnaire, consisting of 25 items using a Likert scale, is designed to measure teachers' level of knowledge in integrating technology, pedagogy, and mathematics. The theoretical construction of this questionnaire encompasses three main dimensions reflecting critical elements of TPMK. The theoretical construction of the TPMK questionnaire refers to the TPACK (Technological Pedagogical Content Knowledge) model proposed by [33]. This model integrates the three main dimensions of T, P, and C in the context of teaching mathematics. This concept has been the basis for many studies on teacher professional development and technology integration in mathematics education [34]. We also consider references to TPMK measurement literature to ensure the questionnaire covers valid and relevant elements [35]. Thus, this questionnaire can provide a comprehensive overview of teachers' TPMK in the context of mathematics teaching by balancing technology, pedagogy, and mathematical knowledge. Both questionnaires use a 5-point scale consisting of categories: Rarely (R), Very Rarely (VR), Sometimes (S), Very Often (VO), and Almost Always (AA). Additionally, the scale used consists of two statements: favorable and unfavorable.

3.4. Data Analysis Technique

Studies apply descriptive analysis to provide an overview of the collected data in this research. In this context, descriptive analysis aims to detail the characteristics of respondents, the level of implementation of the blended learning model, and the level of TPMK among MA teachers. Using descriptive statistics such as mean, maximum, minimum, and standard deviation helps us understand the distribution and variation of respondents' data. In research regarding the impact of implementing the blended learning model post-COVID-19 pandemic on the Technological Pedagogical and Mathematics Knowledge (TPMK) of Madrasah Aliyah (MA) teachers in Indonesia, classical assumption analysis becomes a critical stage before conducting further statistical analysis. Firstly, we conduct normality tests to examine the distribution of observed variable data. You can use normality testing options such as the Kolmogorov-Smirnov or Shapiro-Wilk tests, and the significance of the test results (p-value <

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0.05) can indicate that the data do not follow a normal distribution. If this occurs, you can apply alternatives such as data transformation to meet the normality assumption. Furthermore, we conduct homogeneity of variance tests to ensure uniform variability among groups or conditions. Levene's or Bartlett's tests can be used to test whether variances among groups are equal. If the result is significant, it may indicate variance heterogeneity, and in such situations, we need to consider more appropriate analysis methods for non-homogeneous data. Hypothesis testing is used to examine relationships between specific variables.

Researchers use regression analysis to understand the relationship between the level of blended learning implementation and teachers' TPMK level. The analysis starts by identifying independent and dependent variables, with the level of blended learning implementation as the independent variable and TPMK as the dependent one. After collecting and preprocessing data, they conduct correlation analysis to assess the relationship strength before regression analysis. Next, choose the regression model and establish hypotheses about the relationship between these variables. Statistical software like SPSS is then used for the regression analysis, providing regression coefficient results, significance levels, and other statistics. Evaluating the regression results helps determine their significance and understand whether blended learning implementation significantly impacts teachers' TPMK. Interpretation of the results is crucial, explaining the direction and strength of the relationship between variables. Conclusions drawn from the regression analysis guide the formulation of implications for the learning context in Madrasah Aliyah.

4. Results

4.1. The Application of the Blended Learning Model

The researchers obtained the data on implementing the blended learning model from the responses collected through questionnaire distribution from the research sample. The research sample comprised 32 mathematics teachers in MA in Indonesia. The results of the descriptive statistics are as follows.

Table 1.
Descriptive statistics of the application of the blended learning model.

	N	Minimum	Maximum	Mean	Std. deviation
Model blended learning	32	70	85	79.06	4.370
Valid N (Listwise)	32	-	-	-	-

Based on the descriptive statistical analysis in Table 1, we can interpret that teachers have achieved fairly good results in implementing the blended learning model in mathematics education at schools. The average score for implementing the blended learning model is 79.06, depicting the overall performance of teachers. This figure indicates the middle value of all the data, showing that teachers' average achievement in implementing the blended learning model is relatively high. The range of values obtained, with a minimum score of 70 and a maximum of 85, provides information about the variation or spread of scores among mathematics teachers. The quite wide range indicates variation in the results of implementing the blended learning model among these teachers. A standard deviation of 4.37 provides more detailed information about the level of variation in teachers' scores from the average. Although the range of values is relatively large, a moderate standard deviation suggests that the score variation is not too extreme. Most teachers have uniform levels of achievement, although there is some variation. Thus, these analysis results indicate that implementing the blended learning model in mathematics education at schools has generally had a positive impact, although there is variation in achievement among teachers. This information can serve as a basis for improving and adjusting the implementation of the blended learning model in the future to enhance the consistency of results and its effectiveness in improving the quality of mathematics education among teachers.

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The responses to implementing the blended learning model are detailed in five indicators: the utilization of the learning model, types of content, engagement in learning activities, digital resources, and collaboration. The results of analyzing these responses are presented in Figure 1.

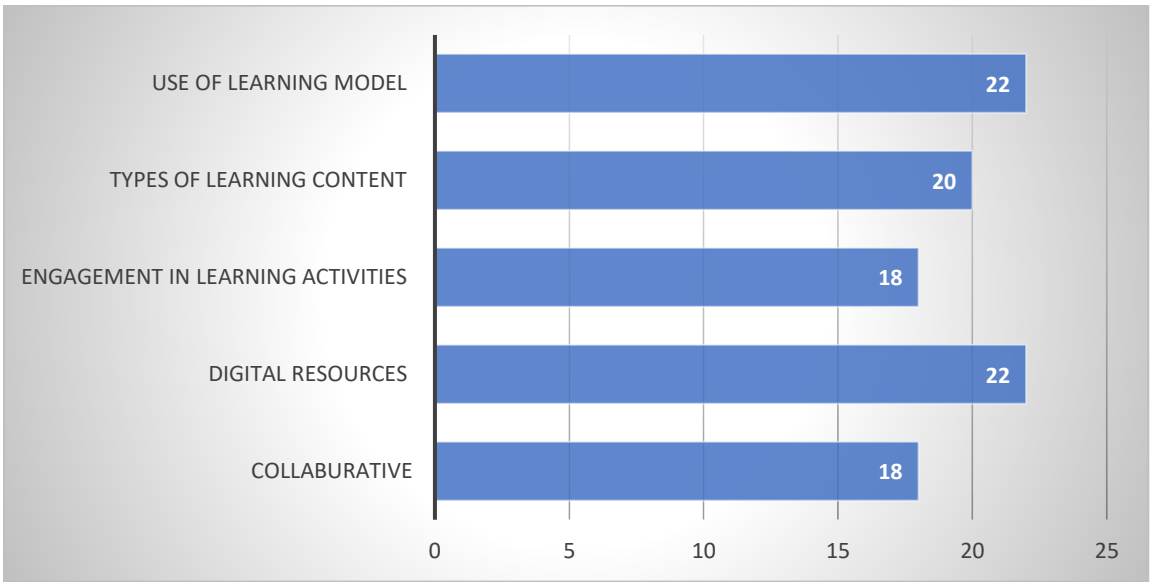

Figure 1.
Blended learning model response indicator.

Based on Figure 1, the utilization of blended learning models and digital resources has the highest percentage, namely 22%. Meanwhile, the indicator of content types reached a percentage of 20%. The smallest percentage is found in the engagement indicators in learning activities and collaboration, which is 18%. This indicates that teachers have successfully implemented blended learning models with good content variation. However, student engagement in learning activities is still less active, and collaboration among students is not yet optimal in mathematics learning activities at MA in Indonesia.

4.2. TPMK Among Madrasah Teachers

The TPMK data were obtained from the distribution of questionnaires collected from a research sample comprising 32 mathematics teachers in MA (Madrasah Aliyah) in Indonesia. The results of the descriptive statistics are as follows.

Table 2.
Descriptive statistics TPMK of mathematics teacher.

	N	Minimum	Maximum	Mean	Std. deviation
TPMK	32	80	95	88.28	3.904
Valid N (listwise)	32	-	-	-	-

Based on the results of descriptive statistical analysis in Table 2 regarding the TPMK (Technological Pedagogical and Mathematics Knowledge) of mathematics teachers in Indonesia, the average TPMK score for mathematics teachers is 88.28. This value depicts teachers' average level of knowledge and skills in integrating technology, pedagogy, and mathematics knowledge. The range of scores obtained, with a minimum score of 80 and a maximum of 95, provides an overview of the variation in TPMK levels among these teachers. This variation may indicate differences in the level of proficiency or understanding in the application of technology, pedagogy, and mathematics knowledge among teachers. Meanwhile, the standard deviation value of 3.904 provides information about the

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distribution or variation of TPMK scores from the average. Although the score range is quite broad, a moderate standard deviation suggests that teacher variation is insignificant. Most teachers have relatively uniform TPMK levels, but some achieve high or low scores. Thus, mathematics teachers in Indonesia have a high overall TPMK level despite the variation among teachers. This information can serve as a basis for developing training programs or more specific approaches to support the improvement of TPMK among mathematics teachers in the region.

The TPMK (Technological Pedagogical and Mathematics Knowledge) of mathematics teachers is measured through 6 indicators consisting of Technological Knowledge (TK), Technological Pedagogical Knowledge (TPK), Pedagogical Knowledge (PK), Mathematical Knowledge for Teaching (MKT), Mathematics Knowledge (MK), and Technological Mathematics Knowledge (TMK). The results of the analysis of teachers' TPMK in MA (Madrasah Aliyah) in Indonesia are presented in Figure 2.

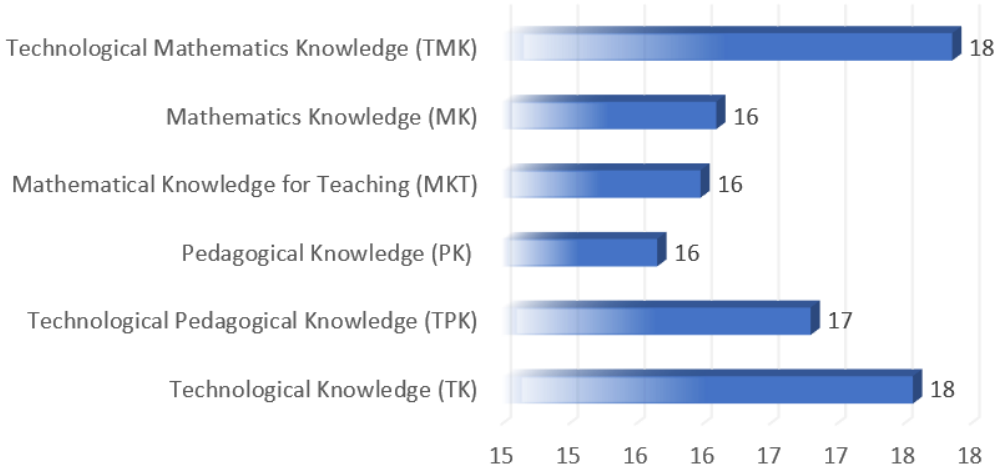

Figure 2.
Math teacher TPMK indicator.

Figure 2 shows that among mathematics teachers in MA (Madrasah Aliyah) Cirebon Regency, the mastery level of TPMK (Technological Pedagogical and Mathematics Knowledge) is relatively consistent. The highest achievements are in Technological Knowledge (TK) and Technological Mathematics Knowledge (TMK), each reaching 18%, while Technological Pedagogical Knowledge (TPK) ranks second with a percentage of 17%. Conversely, the other three indicators, Pedagogical Knowledge (PK), Mathematical Knowledge for Teaching (MKT), and Mathematics Knowledge (MK), only reach the lowest percentages. This indicates that implementing blended learning models positively influences the enhancement of technological abilities in mathematics education.

4.3. The Impact of Blended Learning Model Implementation on TPMK Madrasah Teachers

The simple linear regression equation is Y = a + bX. One can refer to the analysis results in the Coefficients table to determine the value of these regression coefficients. The Coefficients analysis in the study "The Impact of Implementing Blended Learning Models Post-COVID-19 Pandemic on Technological Pedagogical and Mathematics Knowledge of MA Teachers in Cirebon Regency" aims to understand the extent of the contribution of the independent variable, in this case, the implementation of blended learning models, to the dependent variable, namely the TPMK (Technological Pedagogical and Mathematics Knowledge) of MA mathematics teachers in Cirebon Regency. This Coefficients analysis provides information about the significance of the impact of the blended learning model

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implementation variable on the improvement of mathematics teachers' TPMK in the madrasah environment after facing the COVID-19 pandemic.

The purpose of this analysis is to identify the contribution of each variable, namely determining the extent of the contribution provided by the implementation of blended learning models to the development of teachers' TPMK. Thus, the learning model's impact on enhancing teachers' technological, pedagogical, and mathematical knowledge can be measured. Furthermore, the Coefficients analysis is also used to determine the direction of influence of the independent variable on the dependent variable and whether implementing blended learning models has a positive or negative effect on teachers' TPMK. This information is critical in designing more targeted educational strategies and policies. This analysis has a statistical significance level of the influence of the independent variable, in this case, the implementation of blended learning models, where the research can determine whether the resulting impact is significant. The p-value is a critical guide in assessing the significance of this impact. The results are as follows.

Table 2.
Coefficients model.

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	Std. error	Beta		
1	(Constant)	36.928	8.869		4.164	0.000
	Model blended learning	0.650	0.112	0.727	5.799	0.000

Note: a. Dependent variable: TPMK.

Based on the table, we can conclude that the value of a = 36.928, which is a constant, indicates that without applying the blended learning model in mathematics learning, the TPMK value remains consistently at 36.928. Meanwhile, the value of b = 0.650 indicates that for every 1% increase in the application of the blended learning model, the TPMK of mathematics teachers will increase by 0.650. With a positive regression coefficient, we can conclude that applying the blended learning model positively impacts the TPMK of mathematics teachers in MA Indonesia. The regression equation is Y = 36.928 + 0.650 X. Furthermore, based on the table, the significance value (Sig.) is known to be 0.000, smaller than the probability of 0.05. Thus, it can be concluded that H0 is rejected and Ha is accepted, indicating a significant impact of the application of the blended learning model after the COVID-19 pandemic on the Technological Pedagogical and Mathematics Knowledge (TPMK) of MA teachers in Cirebon Regency. The calculated t value is 5.799, with $\alpha/2 = 0.005/2 = 0.025$ and df = n - 2 = 32 - 2 = 30, obtaining a t-table value of 2.037. Since the calculated t value of 5.799 is greater than 2.037, Ho is rejected, and Ha is accepted, indicating a positive impact of the application of the blended learning model after the COVID-19 pandemic on the Technological Pedagogical and Mathematics Knowledge (TPMK) of MA teachers in Indonesia.

Furthermore, the Model Summary Analysis provides an overall picture of how well the statistical model used in the study explains variations in the teachers' TPMK data. In other words, its main purpose is to measure the effectiveness of the regression model used to understand the correlation between the independent variable (the application of the blended learning model) and the dependent variable (teachers' TPMK). This analysis shows how well the statistical model fits the observed data. This is reflected in the R-square value (coefficient of determination), which measures the proportion of variability in the dependent variable that the independent variable can explain. The higher the R-square value, the better the model explains variations in the data. Additionally, this analysis reveals information on the statistical significance of the model, which researchers can ascertain from the Sig. F. If the Sig. F value is smaller than the significance level (usually 0.05), so researchers can conclude that the entire model significantly contributes to explaining the variation in the data.

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Table 3.
Model summary.

Model	R	R square	Adjusted R square	Std. error of the estimate
1	0.727[a]	0.529	0.513	2.725

Note: a. Predictors: (Constant), Model blended learning.
b. Dependent variable: TPMK.

Based on the data found in the table, an R-squared value of 0.529 is obtained. This value reflects that utilizing blended learning models in mathematics education contributes approximately 52.9% to mathematics teachers' TPMK (Technological Pedagogical and Mathematical Knowledge). Meanwhile, around 47.1% of the variation in TPMK among MA teachers in Indonesia is influenced by other factors not investigated in this study. Thus, it can be concluded that implementing blended learning models has a positive impact of approximately 52.9% on the TPMK of mathematics teachers in MA Indonesia. This positive impact indicates that the increasing use of blended learning models in mathematics education at schools will improve TPMK among mathematics teachers in MA Indonesia.

5. Discussion

The results of this study indicate that implementing the blended learning model among mathematics teachers in MA post-COVID-19 pandemic can be categorized as quite reasonable. Mathematics teachers in Indonesia actively adopt technology in learning, creating an environment that integrates online and face-to-face components. The COVID-19 pandemic has triggered a shift in the learning paradigm, where mathematics teachers are increasingly open to innovation and technology integration in the teaching process. It is important to note that the pandemic has urged mathematics teachers to adapt to these changes and respond quickly to distance learning needs[17][18]. Adopting the blended learning model as a response to the pandemic has proven to be a practical step in creating a more flexible and interactive learning experience [19][20]. This model allows mathematics teachers to incorporate technological elements into face-to-face learning, creating a more dynamic learning experience.

These findings have positive implications for the professional development of mathematics teachers. According to Kalyani & Rajasekaran[38], teachers can enhance their technological skills and incorporate innovation into teaching methods. In this context, the research results indicate that the pandemic has provided opportunities for positive transformations in teaching mathematics in Madrasah Aliyah. Meanwhile, the innovative steps taken by mathematics teachers in implementing blended learning enrich students' learning experiences. According to Halverson & Graham [39], a learning environment that includes both online and face-to-face components provides opportunities for students to engage actively, promoting a deeper understanding of the subject matter. Adopting the blended learning model post-COVID-19 pandemic among mathematics teachers in Indonesia has successfully enhanced the flexibility and interactivity of learning and positively contributed to teachers' professional development in mastering learning technology.

Teachers' understanding of the interconnection between technology, pedagogy, and mathematical knowledge in Madrasahs Aliyah Indonesia demonstrates positive outcomes. Madrasah Aliyah teachers exhibit proficient TPMK levels, reflecting their ability to integrate technology into mathematics teaching strategies. These findings carry positive implications for enhancing the quality of mathematics education in the madrasah environment. In this context, improving teachers' understanding of TPMK reflects a positive response to the demands of the times, which require teachers to have interdisciplinary skills [23][24]. Strong connections between technology, pedagogy, and mathematical knowledge are the foundation for creating more relevant and practical learning experiences [19]. Madrasah Aliyah teachers in Indonesia can integrate these elements well, resulting in more dynamic and contextual learning experiences.

The improvement suggests that mathematics teachers in madrasahs are ready to adapt and implement innovations in mathematics education. According to Ferdig [41], a good understanding of

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the interconnection between technology, pedagogy, and mathematical knowledge is crucial in enhancing the effectiveness of teaching methods and ensuring that students gain a deep understanding of the subject matter. Therefore, madrasah aliyah teachers in Indonesia have reached a good TPMK level, depicting readiness to integrate technology into mathematics education. This readiness positively contributes to improving the quality of mathematics education in madrasahs, keeping up with the times, and meeting the demand for interdisciplinary skills in the education sector.

Implementing blended learning models significantly positively impacts the TPMK of madrasah Aliyah teachers in Indonesia. The research findings indicate that integrating technology into mathematics education through the blended learning approach enhances understanding of mathematical concepts and strengthens the pedagogical and technological aspects of teachers' knowledge. With the implementation of blended learning, teachers experience an improvement in their abilities to design and manage technology-based learning [8], [9]. This improvement includes using digital tools, online resources, and online learning platforms [42]. These positive impacts directly contribute to the quality of mathematics education in madrasahs aliyah in Indonesia.

The teachers can enhance their technological skills and integrate these aspects with pedagogical expertise in effectively delivering mathematical content[3]. Thus, implementing blended learning enhances technical aspects and strengthens the overall quality of mathematics teaching [43] [36]. These findings have significant implications for improving the quality of mathematics education at the madrasah level. According to, enhancing TPMK achieved through implementing blended learning can be a foundation for further developing innovative teaching methods [40]. Overall, these findings align with previous research indicating that implementing blended learning can be an effective strategy for enhancing the quality of mathematics education [44], in line with technological advancements and contemporary demands [45].

6. Conclusion

The research findings indicate that implementing blended learning models among mathematics teachers in Madrasah Aliyah significantly positively impacts the understanding of mathematical concepts and teachers' ability to manage technology-based learning. Mathematics teachers actively adopt technology in the learning process, creating a learning environment that combines online and face-to-face components. The teacher's understanding of the interconnection between technology, pedagogy, and mathematical knowledge is also considered exemplary. Madrasah aliyah teachers in Indonesia demonstrate proficient TPMK levels, illustrating their ability to integrate technology into mathematics teaching strategies. However, the limitations of the research lie in the limited geographical scope and external factors such as differing technological infrastructures in other regions. Therefore, we recommend conducting further study with a broader sample, providing more extensive training and support for teachers in developing technical, pedagogical, and mathematical knowledge skills, and continuing to monitor and evaluate the implementation of blended learning models to ensure continuous improvement in the quality of mathematics education in madrasahs aliyah.

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Ethical Considerations:

In the study on implementing blended learning within the Technological Pedagogical and Mathematics Knowledge (TPMK) framework to enhance mathematics teachers' competence, several ethical considerations must be addressed to ensure the study's integrity and respect for participants. First,

participants must provide informed consent before participating, with a full understanding of the study's purpose, procedures, risks, benefits, and their right to withdraw at any time. The privacy of participants should be protected through anonymity and the confidentiality of collected data, which must be securely stored and accessed only by authorized personnel. The study design should prevent harm, minimizing psychological or emotional risks related to performance evaluations or the use of new technologies. Additionally, participant selection must be fair and inclusive, avoiding discrimination, and ensuring that the benefits of the study, such as professional development opportunities, are equitably distributed. Transparency and honesty are crucial, with clear and accurate information provided about the study, and any conflicts of interest disclosed. Finally, the study should aim to produce positive outcomes that contribute to the professional growth of mathematics teachers and the improvement of educational practices. By adhering to these ethical considerations, the study will uphold the highest standards of scientific validity and social responsibility.

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